Combining Ability For Earliness And Yield Among South Sudanese F₁ Sorghum Genotypes

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ABSTRACT

The development of staygreen genotypes through hybridization is an important food security strategy in the semi-arid tropics. This study used 36 sorghum synthetics obtained from a 6 x 6 full diallel mating design. The parents, F1 progenies and their reciprocals showed significant difference for days to flowering suggesting their diversity with regard to this triat. There were significant differences among the maternal and non-maternal effects implying that maternal genes play a greater role in regulating maturity. There were higher genetic predictability ratios for days to flowering, panicle weight and grain weight, suggesting that additive gene action played a bigger role than non-additive genes in the control of these traits. The study identified parental lines, ICSV III IN, B5 and Macia as exhibiting earliness that can be exploited in the breeding program for drought evading hybrids. Similarly, the F1 crosses B35 x Okabir, Lodoka x B35, Okabir x Macia, ICSV II IN x Macia, ICSV III IN x Akuorachot, Lodoka x Akuorachot and Lodoka x Okabir were identified as drought evading synthetics while F1 crosses, B35 x Akuorachot, B35 x Macia, Lodoka x B35, ICSV III IN x Macia, and Lodoka x Macia were identified as high yielding synthetics.

Keywords: Sorghum, drought stress, earliness, yield, screening, South Sudan.

1. INTRODUCTION

The development of staygreen genotypes is an important food security strategy for drought prone agro ecologies of Semi-arid tropics (Ngugi et al., 2013). Staygreen trait enhances plant growth and reproduction under drought stress conditions (Walulu, 1991; Staggenborg, 2010). The trait is correlated with earliness, higher yield and drought stress tolerance which are beneficial traits for subsistence farmers who rely on rainfed farming (Acquaah et al, 2012).

Staygreen trait enhances grain yield by reducing source – sink through canopy size reduction (Borrell et al., 2011; Thomas and Ougham, 2014). The better yield performance among staygreen genotypes is due to their high efficiency in converting absorbed water into biomass and grain yield as well as sustained photosynthate flow through sustained stability of photosynthetic machinery sunder severe drought stress condition (Beyene et al., 2015; Borrell, 2000; Tesfamichael et al., 2015 ; Harris et al., 2018).

Staygreen trait is governed by a major gene (Walulu, 1991). Recent advances in genetic mapping have discovered four main staygreen QTLs namely Stg2, Stg1, Stg3 and Stg4 (Subudhi et al.,2000). These staygreen QTLs confer staygreen trait, earliness and yield (Beyene et al., 2015; Sanchez et al., 2002; Subudhi et al., 2000).

Direct and indirect selection approaches are widely used staygreen screening techniques. Direct approach uses environmental conditions in which the onset of stress factors is uniform and predictable whereas indirect uses well managed and stress environments (Abdipur et al., 2013; Beyene et al., 2015). Selection under both optimal

and drought conditions represents the ideal screening approach for yield and yield stability (Tuinstra et al., 1997). To achieve this, both visual scoring of leaf and plant senescence and genomic tools such as marker assisted selection (MAS) can be used to select for ideal staygreen genotypes (Reddy et al., 2014)

Most breeding programs employ pedigree and recurrent selection methods to develop staygreen candidate populations (Beyene et al., 2015). Introgression of staygreen trait is easily achieved because of high heritability of staygreen loci presence in donor parents B35 and E-36-1(Subudhi et al., 2000 ; Reddy et al., 2007; Thomas and Ougham, 2014). Selection criteria for staygreen genotypes are best executed under controlled and drought-stress environments because of the polygenic nature of trait and high influence of genotype x environment interaction (Beyene et al., 2017).

Genetic information on combining ability of parental lines and crosses on one hand is important in making choice of breeding procedure, method of selection and superior parental lines (Acquaahet al, 2012). Full diallel design on the other hand provides efficient assessment of potent parents, estimate of additive and dominance genetic effects, genetic gain from both additive and non-additive genetic variances, effects of reciprocal, subsequent partitioning of reciprocal into maternal and nonmaternal effects and the gene action controlling them.(Fasahat et al., 2016)

Partitioning of genetic effects into general and specific combining ability will generate powerful information about the roles of each parent when it is used as male and female (Girma et al., 2011). The study will also generate valuable genetic information on the inclusion of reciprocal crosses with regards to induction of earliness and yield increment. (Mahgoub, 2011)

Success in generating good combiners relies much on broader and diverse genetic background the breeder hybridizes and the choice of powerful mating design that enables estimate and wider inference of various gene effects underpinning the triat of interest (Kumar, 1985).

The aims of this study were to select for genotypes combining earliness and yield under drought stress condition for improved food and nutritional security in drought prone areas of South Sudan.

2. MATERIALS AND METHODS

2.1 SITE DESCRIPTION

The study was carried out at ICRISAT-Nairobi field station at Kiboko in Makueni County in the year 2016 and 2017. Kiboko is located at 2" 20 S latitudes and 37 "45" E longitude. Kiboko lies in warm low-land of the semi-arid zone of eastern Kenya with an altitude of 900m above sea level. The area receives an annual rainfall of 604 per annum spread over a short rain season with the maximum temperature of 29.4^0C and minimum temperature of 16.6^0C

2.2 GERMPLASM

The genetic materials used in this study involved three farmer preferred landraces (Akuorachot, Okabir and Lodoka) from South Sudan collection and three staygreen donor parents (B35, ICSV 111 IN and Macia) obtained from ICRISAT- Nairobi (Table 4.1). The six parental lines were part of a 12 x 12 full diallel mating design that was conducted in a long rain growing season of 2016 in Kiboko field station. Six parental lines failed to produce their reciprocals and were discarded for this study.

2.3 EXPERIMENTAL DESIGN

The 36 crosses and parents obtained from a 6 x 6 full diallel mating design (Table 4.1) were laid down in a randomized complete block design with two replications. Replicates were spaced at 1.5 m; inter row and intra-row spacing were 70cm and 20 cm respectively. The experiment was well irrigated from sowing to anthesis stage where irrigation was withheld for drought stress to commence.

Table 1.1 Parental lines, F1s and reciprocal crosses in a 6 x 6 complete diallel mating design

	Lodoka	ICSV III IN	B35	Okabir	Akuorachot	Macia
Lodoka		X	X	X	X	X
ICSV III IN	X		X	X	X	X
B35	X	X		X	X	X
Okabir	X	X	X		X	X
Akuorachot	X	X	X	X		X
Macia	X	X	X	X	X	

2.4 DATA COLLECTION

The data collected included:

- Days to 50% flowering; was collected when 50 percent of the plants had flowered
- Panicle weight (g); was recorded by weighing the panicles per plot
- Grain weight (g): Was recorded by weighing total grain weights per plot
- 100-seed weight: Was recorded by weighing 100-seeds per plot

2.5 DATA ANALYSIS

Data collected over one season were subjected to SAS statistical software using GLM procedures based on Griffing method I for full diallel. The fixed model was used to separate GCA and SCA and reciprocal effects. Replication and block effects were random, and the rest were considered as fixed variables.

2.5.1 GRIFFING METHOD I, MODEL I (FIXED MODEL)

Griffing method I, model I was used because of its ability to utilized parents, F1s and reciprocals to generate important genetic information required to evaluate the genetic component of these parental lines that were drawn from South Sudan collection and ICRISAT-Nairobi germplasm repository. Block and genotype effects were fixed as provided for in equation (8).

$X= \mu + G + B + GB + E_{(rl)}$ …………………………………………….. (7)

Where X= observation, U= means of genotypes, G= effects due to genotypes B= block effects, GB= interaction between genotypes and blocks, and E= error due to environment.

When genotypes are assigned to the block, the genotypic effects G would be equated to ;

G= g_i + g_j + s_{ij} + r_{ij}……….…………………………………………………….. (8)

By substituting G in equation (7) by equation (8) , the whole equation would be

X= μ + g_i + g_j + s_j + $r_{j +}$ B + GB + E ® ………………………………….. (9)

Where:

μ= the population mean

gi, gj = General combining effect for the Ith and J^{th} parents

Sij= is the specific combining ability effect of the cross between the Ith and J^{th} parents such that $S_i=S_j$.

r_{ij}= is the reciprocal effect involving the reciprocal crosses between the Ith and J^{th} parents such that $r_i=r_j$ and

e_{ijkl}= is the experimental error due to environmental effect associated with the $ijkl^{th}$ which is assumed to be uncorrelated and normally distributed with zero mean and variance VE.

b= Number of replicates

c=Number of plants

The restrictions imposed on combining ability estimates were Sg_i = 0 and Ss_{ij} = 0 for all GCA and SCA effects,(Griffing 1956).

Baker ratios or genetic predictability ratios to determine the effects of additive and non-additive gene actions were calculated according to Baker, (1978.)

Baker ratios= $\frac{GCA}{SCA} = \frac{(2MS_{GCA})}{(2MS_{GCA}+MS_{SCA})}$ …………………………………………(9)

Where MS_{GCA}= Mena square of general combining ability and MS_{SCA} = mean square value of specific combining ability

3. RESULTS

3.1 ANALYSIS OF VARIANCE FOR THE DIFFERENT TRAITS AMONG THE SORGHUM GENOTYPES

The mean square for the traits under study showed no significant ($P \leq 0.05$) differences for the genotypes, reciprocal, maternal and non-maternal effects except for days to flowering (Table 4.1) Predictability ratios showed high contribution of additive genetic effects relative to non-additive genetic effect for days to flowering, panicle weight and grain weight

Table 1.2 Means square for all the traits studied under drought stress conditions

Source of variation	DF	DFL	PWT	GWT	HSW
REP	1	30.680556ns	377.66681ns	722ns	2.13555556ns
Genotypes	35	171.680556**	417.42757ns	287.66241ns	0.53136508ns
GCA	5	724.061ns	394.745ns	108.623ns	0.38261
SCA	15	78.868ns	374.911ns	198.186ns	0.87631ns

REC	15	80.367**	467.505ns	436.819ns	0.236ns
MAT	5	115.333**	607.622ns	425.809ns	0.24417ns
NMAT	10	62.883**	397.447ns	442.323ns	0.23192ns
Error	35	15.309127	436.10686	414.86971	0.4195556
Total	71				
Baker's ratios		0.9	0.6	0.5	0.4

DF= days to flowering, PWT= panicle weight, GWT= grain weight and HSW= 100-seed weight, GCA= general combining ability,

MAT= maternal effect. NMAT= nonmaterial effect ns= not significance,* significant at P<0.05 and ** = significant at P<0.01.

3.2 MEAN PERFORMANCE OF F1 AND RECIPROCAL CROSSES BETWEEN SOUTH SUDAN FARMER PREFERRED LINES AND ICRISAT ELITE LINES

Mean values of F1s and reciprocals are presented in table (4.2). The earliness trait was exhibited by the F1 cross, Macia x ICSV 111 IN (55 days), reciprocal combinations cross, ICSV 111IN x Macia (56 days), and parental cross ICSV 111 IN x ICSV 111 IN (55 days). However, extreme lateness was recorded by the combinations cross, Okabir x Akuorachot (93 days) and parental Lodoka x Lodoka (85 days).

The highest panicle weight was recorded for F_1 generation cross between, Okabir x Macia (93.05g) and ICSV 111 IN x Lodoka (81.45g). While the highest grain weights were given by F1 generation cross between, Okabir x Macia (76.9g) and ICSV 111 IN x Lodoka (66.55g). The highest 100-seed weight was recorded among the cross, B35 x ICSV 111 IN (4.15g) and the reciprocal cross, ICSV 111 IN x B35 (4.1g), (Table 4.2).

Table 1.3 Means performance per plot of F_1 progenies and reciprocal crosses between South Sudan farmers preferred lines and ICRISAT elites lines

Genotypes	DF	PWT (g)	GWT (g)	HSM (g)
Lodoka x Lodoka	86	42.8	34.2	3.2
Lodoka x ICSV111IN	68	66.8	43.7	3.6
Lodoka x B35	75	33.7	25.6	3.2
Lodoka x Okabir	82	59.4	51	3.1
Lodoka Akuorachot	72	38.7	30.3	3.5
Lodoka x Macia	64	55	40.1	2.5
ICSV111IN x Lodoka	64	81.5	66.6	3.1
ICSV111IN x ICSV111IN	55	45.2	35.9	2.3
ICSV111IN x B35	56	52.4	41.7	4.1
ICSV111IN x Okabir	67	65	51.5	2.7
ICSV111IN x Akuorachot	58	51.2	39.6	3.0
ICSV111IN x Macia	56	53.6	40.7	2.7
B35 x Lodoka	63	79.2	49.9	2.4
B35 x ICSV111IN	56	61.3	47.9	4.2
B35 x B35	62	44.4	30.5	1.9
B35 x Okabir	65	52.2	39.9	2.9
B35 x Akuorachot	65	66.5	53.3	2.5
B35 x Macia	57	62.2	45.9	3.0
Okabir x Lodoka	72	56	47.4	3.3
Okabir x ICSV111IN	70	25.1	18.1	3.4
Okabir x B35	73	44.9	33.7	2.6
Okabir x Okabir	78	71.2	46.6	2.4
Okabir x Akuorachot	93	44.2	33.6	2.5
Okabir x Macia	76	93.1	76.9	3.2
Okabir x Lodoka	71	65.3	56.2	3.2
Akuorachot x ICSV111IN	58	38.3	33.6	3.7
Akuorachot xB35	72	59.7	47.9	2.9

Genotypes	DF	PWT (g)	GWT (g)	HSM (g)
Akuorachot x Okabir	79	51.7	42.5	2.5
Akuorachot x Akuorachot	62	40.9	30.6	3.0
Akuorachot x Macia	65	41.8	27.8	3.0
Macia x Lodoka	73	53.8	43.3	3.4
Macia x ICSV 111 IN	55	59.9	44.4	2.4
Macia xB35	74	45.3	32.9	3.4
Macia x Okabir	60	56	23.3	2.9
Macia x Akuorachot	67	59.4	46.3	3.3
Macia x Macia	71	81.1	58.8	3.8
Mean	67.5972	55.5	41.9778	2.99444
CV%	5.78824	45.5934	48.5218	21.6311

Key; DFl= days to 50% flowering. PWT= panicle weight, GWT= grain weigh and HSW= 100-seed weight, 1=Lodoka, 2= ICSV111IN, 3= B35, 4= Okabir, 5= Akuorachot and 6= Macia, *= 0.05, **= 0.01, ***= 0.001

3.3 GENERAL COMBINING ABILITY ESTIMATES AMONG THE SORGHUM GENOTYPES

Results for estimates of general combining ability effects are presented in table (4.3). Negative and significant general combining ability (GCA) effects for days to flowering was recorded by three parental lines, ICSV 111 IN (-7.97), B35 (-2.9) and Macia (-2.1g), indicating that they are good parental sources of genes for earliness. The superior general combiners with positive GCA effects for panicle weight were Macia (6.4g) and Okabir (1.9g). Highest and positive GCA for grain weight was recorded by parental lines, Lodoka (4.31) and ICSV III IN (2.3g). For 100 seed weight, three parental lines, Macia (0.28), Lodoka (0.12) and ICSV 111 IN (0.11) recorded positive GCA effects (Table 4.3).

Table 1.4 Estimate of GCA effects on six sorghum parental lines

Genotypes	DFL	PWT	GWT	HSW
Lodoka	5.3	0.53	4.31	0.12
ICSV111IN	-7.97***	-1.73	2.39	0.10
B35	-2.84**	-1.66	-3.42	-0.10
Okabir	6.8	1.98	-0.80	-0.18
Akuorachot	0.90	-5.64	-4.03	-0.01
Macia	-2.14**	6.3	1.57	0.08
V (g)	0.532	22.23	14.41	0.015
V (g$_i$ −g$_j$)	1.276	53.36	34.6	0.035

Key: DFL= days to flowering, PWT= panicle weight, GWT= grain weight, HSW= hundred seed weight, 1=Lodoka, 2= ICSV111IN, 3= B35, 4= Okabir, 5= Akuorachot and 6= Macia *= 0.05, **= 0.01, ***= 0.001

3.4 SPECIFIC COMBINING ABILITY EFFECTS AMONG THE SORGHUM HYBRIDS

Results for estimates of specific combining ability effects on F1 hybrids are presented in table (4.4). For days to flowering, negative specific combining ability effects was recorded by F1 generation crosses, B35 x Okabir (-2.5), Lodoka x B35 (-1.28), Okabir x Macia (-1.08) ICSV III IN x Macia (-3.8), ICSV III IN x Akuorachot (-2.8) and ICSV II IN x B35 (-10.3). The F1 hybrids cross, B35 x Akuorachot (14.98) recorded the highest and positive SCA for panicle weight while Lodoka x Macia (30g) and B35 x Akuorachot (14.6g) gave the highest

and positive SCA for grain weight. Highest and positive SCA for 100-seed weight was recorded by F1 generation crosses, B35 x Macia (1.1g) and ICSV III IN x B35 (1.1g)

Table 1.5 Estimate of Specific combining ability effects on sorghum F1 progenies

Genotypes	DFL	PWT	GWT	HSW
Lodoka x ICSV111IN	1.1	19.5	11.9	0.13
Lodoka x B35	-1.3	1.9	-6.5	-0.23
Lodoka x Okabir	-2.9	-0.51	2.3	0.21
Lodoka x Akuorachot	-2.3	1.3	-0.4	0.20
Lodoka x Macia	-10.3	6.0	10.2	-0.24
ICSV111IN x B35	-1.3	4.7	2.4	1.1
ICSV111IN x Okabir	2.1	-10.6	-10.2	0.1
ICSV111IN x Akuorachot	-2.8	-3.4	-5.2	0.24
ICSV111IN x Macia	-5.8	3.5	7.5	0.29
B35 x Okabir	-2.5	-7.3	-2.4	0.04
B35 x Akuorachot	2.8	14.8	14.6	-0.19
B35 x Macia	3.0	1.3	3.97	1.1
Okabir x Akuorachot	10.7**	-3.9	-0.47	-0.3
Okabir x Macia	-1.0	-0.98	1.2	0.3
Akuorachot x Macia	7.2	-2.2	0.83	0.04
V (S_{II})	1.0631	44.464	38.885	0.2914
V($S_{II} - S_{ij}$)	10.2061	426.85	373.299	0.27970
V ($S_{ii} - S_{jj}$)	10.2061	426.85	373.299	0.27920
V ($S_{ii} - S_{ijk}$)	7.6546	320.18	279.975	0.20978

Key; DFL= days to flowering, PWT= panicle weight, GWT= grain weight and HSW= hundred seed weight 1=Lodoka, 2= ICSV111IN, 3= B35, 4= Okabir, 5= Akuorachot and 6= Macia, *= significant 0.05, **= significant at 0.01, ***= 0.001

Results for estimates of reciprocal combining ability (RCA) effects are presented in table (4.5). The RCA effects for days to flowering were negative and significant for reciprocal crosses, Macia x Lodoka (-4.3), Okabir x B35 (-4) and Macia x B35 (-8, 3). While highest and positive reciprocal effects for days to flowering were given by Macia x Okabir (8). Akuorachot x Okabir (7) and Okabir x Lodoka (5.3). For panicle weight, highest and positive panicle weight was recorded by reciprocals crosses Okabir x ICSV III IN (19.9) and Macia x Okabir (18.5). As regards grain weight, highest and positive reciprocal effects were recorded by reciprocal crosses Maxia x Okabir (26.8) while highest and positive reciprocal effects for 100-seed weight was recorded by reciprocal cross, B35 x Lodoka (0.4).

Table 1.6 Estimates of combining ability effects on reciprocal crosses between South Sudan farmer preferred sorghum lines and ICRISAT elite lines

Genotypes	DFL	PWT	GWT	HSW
ICSV III IN x Lodoka	2	-7.4	13.6	0.3
B35 x Lodoka	6.3*	-22.8	-12.2	0.4
Okabir x Lodoka	5.3*	1.7	1.8	-0.1
Akuorachot x Lodoka	0.5	-13.3	-12.9	0.2
Macia x Lodoka	-4.3*	0.6	-1.6	-0.4
B35 x ICSV III IN	0.1	-4.5	-3.1	-0.02
Okabir x ICSV III IN	-1.5	19.9	16.7	-0.4
Akuorachot x ICSV III IN	-0.2	6.5	3	-0.4

Macia x ICSV III IN	0.5	-3.1	-1.9	0.12
Okabir x B35	-4*	3.6	3.1	0.2
Akuorachot x B35	-3.5	3.4	2.7	-0.2
Macia x B35	-8.3***	8.5	6.5	-0.2
Akuorachot x Okabir	7***	-3.8	-4.5	0.1
Macia x Okabir	8***	18.5	26.8	0.12
Macia x Akuorachot	-0.8	-8.9	-9.3	-0.15
V(r)	3.8273	160.069	103.717	0.10489
V ($r_{ij} - r_{kj)}$	7.6546	329.139	207.485	0.20978

Key, DLF= days to flowering, PWT= panicle weight, GWT= grain weight and HSM= hundred seed mass, *= 0.05, **= 0.01, ***= 0.001

4. DISCUSSION

4.1 GENERAL COMBINING ABILITY ESTIMATES AMONG THE SORGHUM GENOTYPES

The parents, F1 progenies and their reciprocals showed significant differences for days to flowering suggesting their diversity with regard to physiological maturity. There were significant differences among the maternal and non-maternal effects implying that maternal genes play a greater role in regulating maturity There were higher genetic predictability ratios for days to flowering, panicle weight and grain weight, suggesting that additive gene action played a bigger role than non-additive genes in the control of these traits. Similar findings were reported by (Padhar et al.,, 2013; Chandra et al., 2014) The absence of significance among the general and specific combining ability effects for panicle weight, grain weight and 100-seed weight could be attributed to the effect of epistatic gene action..

Negative significant general combining ability effects (GCA) were noted for days to flowering for parents ICSV 111 IN, B35 and Macia, suggesting that these parents had the earliness trait that can be exploited for the development of drought-stress evading hybrids. Previous research have reported negative GCA effects for days to maturity (Girma et al., 2011; Sally et al., 2017). Similarly (Meng et al., 1988; Siddiqual and Baig, 2001) have advocated for the significant roles of negative GCA relative to positive GCA in conferring earliness trait in sorghum. The parents Lodoka, Okabir and Akuorachot exhibiting positive GCA for days to flowering implied lateness, thus conferring the late physiological maturity.

With regard to the panicle weight, the parental lines with positive and high GCA values are chosen the superior combiners. Genotypes Macia and Okabir recorded positive GCA and high mean values for panicle weight, implying the important roles of GCA than SCA in contributing to desirable panicle weight. Similar findings were reported by (Meng et al., 1999' Girma et al., 2011) who identified superior parents with positive GCA for the interest traits.

With regard to the combining ability for grain yield, the parents Macia and ICSV 111 IN showed positive GCA effects implying that they are good combiners for grain yield compared to parental lines B35, Okabir and Akuorachot which showed inferiority for grain weight. The significant of GCA in discriminating superior

parents from inferior parents for grain yield was reported by (Tourchi and Rezal, 1996). High GCA for grain yields is a result of additive gene action, implying the importance of additive gene action in the inheritance of yield trait. (Meng et al., 1998).

For the 100-Seed weight, the parent Macia and ICSV 111 IN showed positive GCA suggesting that they are good combiners for this trait. The high GCA effects are governed by genes with additive effects (Sally and Odongi, 2017).

4.2 ESTIMATES OF SPECIFIC COMBINING ABILITY EFFECTS AMONG THE SORGHUM HYBRIDS

The measure of deviation of a cross from the average performance of the parental genotypes is defined as specific combining ability (Sally and Odongi, 2017). Crosses that gave positive significant SCA for days to maturity induce lateness (Girma et al., 2011).

Significant and negative specific combining ability for days to flowering was exhibited by nine F_1 progenies including, B35 x Okabir, Lodoka x B35, Okabir x Macia, ICSV II IN x Macia, ICSV III IN x Akuorachot, Lodoka x Akuorachot and Lodoka x Okabir. However, crosses that showed significant and negative SCA effect expressed earliness (Girma et al., 2011). Thus, the negative significant SCA exhibited by F1 combination crosses ,Lodoka x B35, Okabir x Macia , Lodoka x Akuorachot might be due to additive gene effect in parent B35, Macia and Akuorachot overriding non-additive gene action in the genetic backgrounds of late parental Okabir and Lodoka.

For panicle weight, the highest and positive SCA effects were recorded by F1 progeny crosses, B35 x Akuorachot, Lodoka x ICSV III IN, Lodoka x B35, ICSV III IN x B35 and ICSV III IN x Macia. Positive and highest SCA effects are chosen when selecting for yield determinants of hybrids (Rao, 1970).

As regards, grain weight, positive and highest SCA was recorded by F1 progenies, B35 x Akuorachot, B35 x Macia, Lodoka x B35, ICSV III IN x Macia, and Lodoka x Macia. High and positive SCA are preferred when selecting for high yield hybrids (Rao, 1970). The F1 progenies that exhibited the highest SCA effects for grain yields resulted from crosses involving high x high, high x low and low x low types of combiners, implying the presence of additive x additive, additive x dominance and dominance x dominance in their genetic backgrounds. Similar results were reported by (Padhar et al., 2013; Chandra et al., 2014; Mutava, 2014;). Highest and positive SCA effects emanating from involvement of superior x superior combiners as in F1 crosses between, B35 x Macia, ICSV III IN x Macia and B35 x Akuorachot might be due to complementary actions of additive genes in their genetic backgrounds. Similarly, the highest and positive SCA emanating from crosses involving superior x inferior type of combiners as in F1 crosses between, Lodoka x Macia and Lodoka x B35 is due to additive gene action in the superior parents and epistatis gene action in inferior parents acting in a complementary fashion that maximizes grain yield in the inferior parents (Chandra et al., 2014). .

For 100-seed weight, only three out of 15 F1 generation crosses recorded positive and highest specific combining ability (SCA) effects. The F1 progenies, B35 x Macia, B35 x ICSV III IN and Lodoka x Macia were superior for 100-seed weight implying that these crosses could be used as superior genotypes for development of commercial synthetics in drought prone agro ecologies of South Sudan. These findings are in full agreement with (Lyanar et al., 2001; Umakanth et al., 2002; Patill 2004) who had previously reported higher variance of SCA for 100-seed weight. 100-seed weight is an important economic trait that determines grain sorghum prices in the semi-arid tropics where sorghum crop serves as staple food security crop.

4.3 RECIPROCAL SPECIFIC COMBINING ABILITY EFFECTS AMONG THE SORGHUM HYBRIDS

The analysis of reciprocal effects showed no significant differences for days to flowering. Negative reciprocal effects were recorded by reciprocal crosses Okabir x B35, Macia x B35 and Macia x Akuorachot, Macia x Lodoka, implying the roles of maternal genes in contributing to earliness. In reciprocal crosses, Okabir x B35 and Macia x B35, the maternal alleles in maternal parents B35 had contributed to earliness. Similarly, in a reciprocal cross, Macia x Akuorachot, the role of maternal parent, Akuorachot (medium maturing parent) had contributed to medium anthesis. Similar results were reported by (Wu and Matheson, 2001)

For panicle weight, positive and highest reciprocal effects was recorded by reciprocal crosses, Okabir x ICSV III IN, Akuorachot x ICSV III IN and Akuorachot x B35. The high panicle weight in these reciprocal crosses can be traced back to the high performance of maternal parents B35 and ICSV III IN whose maternal genes helped elevate panicle weight in these reciprocal crosses, implying the positive roles of maternal genes in increasing panicle weight.

For grain weight, positive and highest grain weights were recorded by reciprocal cross, Okabir x ICSV III IN, implying the roles of maternal alleles in increasing grain yields. Previous studies by (Wu and Matheson, 2001) had advocated the inclusion of reciprocal crosses in breeding program because of their positive contribution to positive SCA effects useful in selecting for higher grain yield. There were no positive and high reciprocal effects for 100-seed weight, implying that inclusion of reciprocal crosses is not so important when breeding for this trait.

5. CONCLUSION

The study identified significant differences among the maternal and non-maternal effects implying that maternal genes play a greater role in regulating maturity. Genetic predictability ratios were high for days to flowering, panicle weight and grain weight indicating that additive genes play a bigger role than non-additive genes in control of such traits. Negative significant general combining ability effects (GCA) for days to flowering was used to identify parents exhibiting genes for earliness, therefore parents ICSV 111 IN, B35 and Macia were identified as early maturing parents that can be exploited for development of drought evading hybrids.

Significant negative specific combining ability for days to flowering was exhibited by F_1 crosses, B35 x Okabir, Lodoka x B35, Okabir x Macia, ICSV II IN x Macia, ICSV III IN x Akuorachot, Lodoka x Akuorachot and Lodoka x Okabir, implying that these synthetics can be advanced for development of early maturing hybrids and inbredlines. For 100-seed weight, the F1 progenies, B35 x Macia, B35 x ICSV III IN and Lodoka x Macia were superior for 100-seed weight implying that these crosses could be used as superior genotypes for development of commercial synthetics in drought prone agro ecologies of South Sudan. The analysis of reciprocal effects showed no significant differences for days to flowering but negative reciprocal effects were recorded by reciprocal crosses Okabir x B35, Macia x B35 and Macia x Akuorachot, Macia x Lodoka, implying the roles of maternal genes in conferring earliness.

5.1 RECOMMENDATIONS

- Superior sorghum genotypes were identified in this study. These genotypes should be screened across more diverse environments to validate the results
- The superior parents could also be used to develop superior synthetics for release to the drought prone areas of South Sudan

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